# A DATA ACQUISITION AND CONTROL SYSTEM FOR A FLUIDIZED BED COMBUSTION UNIT

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## INTRODUCTION

The Centre for Energy Studies at the Technical University of Nova Scotia is currently developing a small scale fluidized bed combustion unit for domestic heating purposes. The Electrical Engineering Department at the University was called upon to provide the electronics necessary to control and gather operating data on an improved prototype. The purpose of the present system is to develop an efficient control algorithm. If the fluidized bed proves feasible, the hardware can be simplified to an inexpensive microprocessor controller.

## OVERALL SYSTEM DESIGN

The main requirement of the electronic system is to maintain the temperature of the fluidized bed between the limits of $750^{\circ}$ - $950^{\circ}$C. The method of control is to monitor not only the bed temperature but also the stack temperature and concentration of pollutants and then adjust the ratio of fuel and air input to achieve complete combustion. Since the fluidized bed is integrated with a back-up domestic oil-fired hydronic heating system, control of boiler temperature is also a system requirement. In addition alarms are energized and appropriate actions taken when the fluid bed temperature is outside the desired range.

To aid in development of the control algorithm,the fluidized bed and back-up heating unit are fitted with a variety of sensors. Examples include thermocouples for temperatures, gas analyzers for oxygen and carbon monoxide, and pressure transducers for air flow rates. Since the total number and type of sensors is variable, expansion and modification of both hardware and software by the user is highly desirable. With these points in mind, the system of Figure 1. was developed.

The general philosophy is to employ the desktop computer in the role of a "host", controlling data flow and perfoming arithmetic calculations. The host also acts as an interface between the console (user) and the data acquisition unit when system configuration changes are desired. The printer provides a record of the system status and operating conditions.

The next section briefly describes the components selected to realize the system of Figure 1.

### *System Hardware*

Since the project is of a developmental nature it was thought highly desirable to select major components which are general purpose in nature and, hence, useful in future applications. To this end, the STD BUS was selected as the basis of the microprocessor controlled data acquisition unit. The STD BUS was developed by Pro-Log and MOSTEK and is now quite popular. A wide variety of plug-in cards and complete systems are available from manufacturers such as Pro-Log, MOSTEK, Intersil and Analog Devices.

The STD BUS standardizes the physical and electrical aspects of modular 8-bit microprocessor card systems. The standard permits any card to work in any slot of the bussed motherboard which provides internal communication. All other connections to the outside world are by connectors at the opposite ends of the cards. Available cards include all the popular 8-bit processors, memory expansion, digital

I/O, analog I/O, industrial I/O (relays and triacs) and peripheral interfaces.

The data acquisition unit contains 4 plug-in cards, two of which are custom built. Figure 2 shows how the various functions are distributed. The processor card uses an 8085A and has sufficient random access and program memory on-board. With the exception of signal conditioning for low-level signals, the entire analog I/O subsystem is contained on the RTI-1225 card manufactured by Analog Devices Corp. It is designed specifically for interfacing real time analog signals to microcomputer systems. On the input side there are 16 channels multiplexed to a sample and hold amplifier and a 10 bit A to D converter. The output side has 2 channels with 8 bit resolution. Communication is memory mapped and appears as five contiguous address locations which are used to control the functions of the card and pass data to and from the microprocessor.

The custom built cards combine two functions on each. One handles thermocouple signal conditioning and digital I/O while the other contains a real time clock and a UART for interfacing to the desktop computer. Four thermocouples of any type can be handled by the present card, with gain and cold junction compensation software selectable. Additional cards may be added as required. All temperature channels are multiplexed into channel one of the A to D converter, leaving 15 single-ended 0-10 volt analog input channels.

Operating data other than temperatures are supplied by the monitoring instruments (e.g. oxygen analyzer). The outputs from such instruments are in general fully compensated and conditioned 4-20 mA currents or selectable low level voltages. Instruments with 0-10 volt outputs can thus connect directly to the A to D converter. In our system, carbon monoxide and carbon dioxide monitors produce only a 0 - 5 volt output, which still provides adequate resolution and accuracy with a direct connection. Instruments with current loop outputs also connect directly by terminating the loop at the A to D input with a 500 ohm resistor to produce a 2-10 volt signal range. If other low level sensors such as strain guages are required, they can be amplified externally with modules which produce either current loop or 0-10 volt outputs. Examples include the Analog Devices 2B50 series.

The host computer is a desktop unit which does the calculation of the control algorithm and prepares system status information for display at the console and printer. This computer is a Superbrain (Intertech Data Systems, Columbia, South Carolina) based on the Z-80A microprocessor and using the CP/M operating system. It is a self-contained unit having a CRT, keyboard, two floppy disk drives, 64K of memory and 2 I/O ports.

In keeping with the overall philosophy of hardware selection, the printer is a Decwriter LA-120 which provides the user with a very flexible and attractive hard-copy terminal for future use.

*System Software*

The system software was develpped in two stages. First the data acquisition unit program was written in PL/M. Compilation was done on a large time-shared system and the result downloaded to a PROM programmer. Included in the I/O portion is a segment which enabled testing and calibration of the analog hardware as the program was expanded. Following this the host computer program was written and tested a portion at a time with the working data acquisition unit. Rapid development of relatively unsophisticated processing, combined with ease of program maintenance by the users led to the selection of BASIC as the host language.

The main tasks assigned to the data acquisition unit are temporary storage of raw binary data from all sensors, conversion to ASCII of this same data, response to requests by the host computer and monitoring alarm conditions in the fluidized bed. Single letter codes sent by the host initiate any desired actions. Examples include passing of the latest data, adjustment of fuel or air motors, or changes in system configuration such as number of active channels.

PL/M is a programming language designed for Intel's 8 bit microcomputers. The language is structurally similar to PL/I so that programs are somewhat self-documenting and easily altered and maintained. A memory map for the data acquisition unit is shown in Figure 3. The program is stored in read-only memory and the analog I/O subsystem is placed at the top of the 64k address space. This application uses about 1k bytes of the available on board ROM.

The supervisory BASIC program gets the latest data from all sensors, converts to appropriate units and formats and displays this information on the console and printer. Time of day and update interval are provided by the real time clock, which is software settable from the host. For non-linear sensor readings, disk files containing appropriate tables are used for interpolation. Such is the case for all thermocouple readings. The converted data is then utilized by the control algorithm to determine if fuel and air feed corrections are required. If so, this information is passed to the data acquisition unit and out the D to A channels to motor controllers. Finally, a second check on the fluidized bed temperature is done by the host to alert the operator in the event of a failure of the hardware alarms.

*Conclusion*

A data acquisition and control system for a fluidized bed combustion unit has been described. It should be re-emphasized that the developed algorithm can be easily moved to read-only memory in a low cost controller. It is believed that the choice of major components has resulted in a system which is sufficiently general in nature to not only serve the current project but also to prove useful in future applications. The type of system described should find application wherever monitoring, recording and control of analog or digital signals and processes is required.

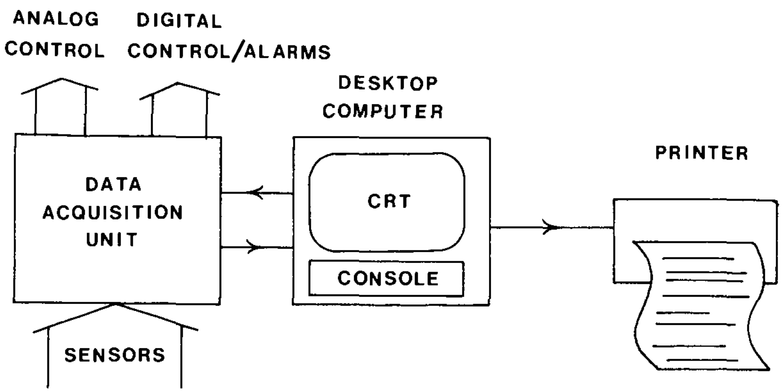


FIGURE 1. OVERALL SYSTEM.

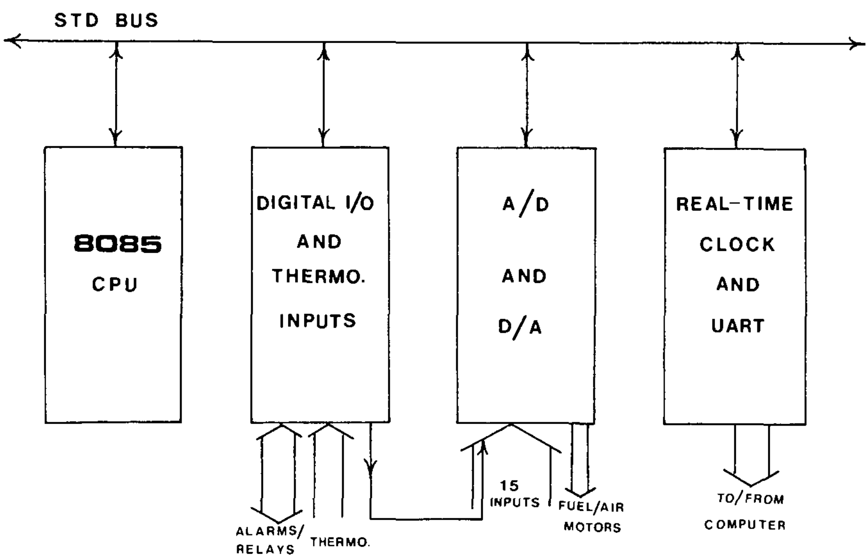


FIGURE 2. DATA ACQUISITION UNIT.

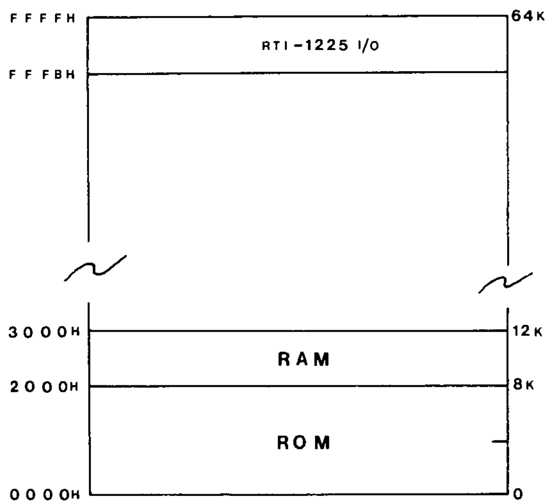


FIGURE 3. D. A. U. MEMORY MAP.